DEVELOPMENT OF ASSEMBLING TIME MAP FOR EMERGENCY ACTION

Sei'ichiro FUKUSHIMA[1], Makoto TAKAHASHI[2] And Harumi YASHIRO[3]

SUMMARY

In order to establish headquarters for seismic countermeasure, it is important to secure the personnel as well as the facilities. In many earthquake scenarios those two items are assumed sound after an earthquake, though the facts are different. Therefore, it comes necessary to estimate the realistic status of those items for the effective actions. This paper describes the development of assembling time map of personnel. The development of assembling time map possesses the following tasks, to estimate regional damage, to estimate individual damage such as bridge collapse, to estimate passage time of each arc, and to search the optimal route from each starting point to destination. Given a scenario earthquake, the regional damage and the individual damage are evaluated in a probabilistic way so that the damage rates are obtained. Passage time of each arc is evaluated reflecting the damage rates mentioned above. Based on the passage time of each arc, the optimal route can be searched. By integrating the methodologies for estimating the damage due to earthquake, the assembling time map can be obtained. Combining this map with the information of the personnel's location, the relationship between the time elapsed after an earthquake and the number of the personnel will be obtained. This method can be used more widely by being combined with the existing GIS system.

INTRODUCTION

In many earthquake scenarios, it is assumed that the headquarter facilities and the personnel required are sound. This assumption, however, may bring the improper emergency action, as suggested in the Great Hanshin Earthquake. For example, Kobe branch office of Kansai Electric Power Company was damaged a lot, so that they had to organize their headquarter for seismic countermeasure in the unexpected place, yielding some delay in establishing it. After Kobe earthquake, a lot of strengthening work have been done for the existing buildings. On the other hand, the estimation for the availability of personnel and/or the upgrading the assembling system have not been considered seriously, though it is very important from the viewpoint of disaster prevention.

It is, therefore, necessary to consider the assembling of personnel reflecting the actual damage, which means the damage of assembling route and that of personnel himself. So far, a lot of knowledge and data regarding to the damage estimation have been accumulated. This system integrates them, so that the realistic estimation of the assembling status after the occurrence of an earthquake will be possible. For example, the followings are obtained as necessary information for estimation; damage probability of each personnel at where he is, a time for commencement of movement, the nearest destination of each personnel, the optimal assembling route, and so on.

This paper introduces the system newly developed for the purpose above, and also shows that it is used with the existing GIS system.

FRAMEWORK OF SYSTEM

Figure 1 illustrates the framework of the system proposed. The system consists of three modules; search of the optimal route, calculation of assembling time and assessment of assembling status. The first module evaluates the passage time of each arc meaning the road connecting the nodes, and finds out the optimal route from the starting node to the destination node using Dijkstra's method. The second module evaluate the assembling time

[1] Seismic Engineering Department, Tokyo Electric Power Services Co., Ltd., Tokyo, Japan Fax: +81-3-5818-7608
[2] Seismic Engineering Department, Tokyo Electric Power Services Co., Ltd., Tokyo, Japan Fax: +81-3-5818-7608
[3] Risk Management Department, Tokio Marine and Fire Insurance Co., Ltd., Chiba, Japan Fax: +81-43-299-5423

for each mesh. The last module assesses the assembling status which may be expressed by the relationship between the elapsed time after an earthquake and the expected number of personnel arrived.

The feature of this system is that it combines the damage, such as collapse of buildings and fire expansion, and the passage velocity. This treatment can make it possible to plan more realistic seismic countermeasure.

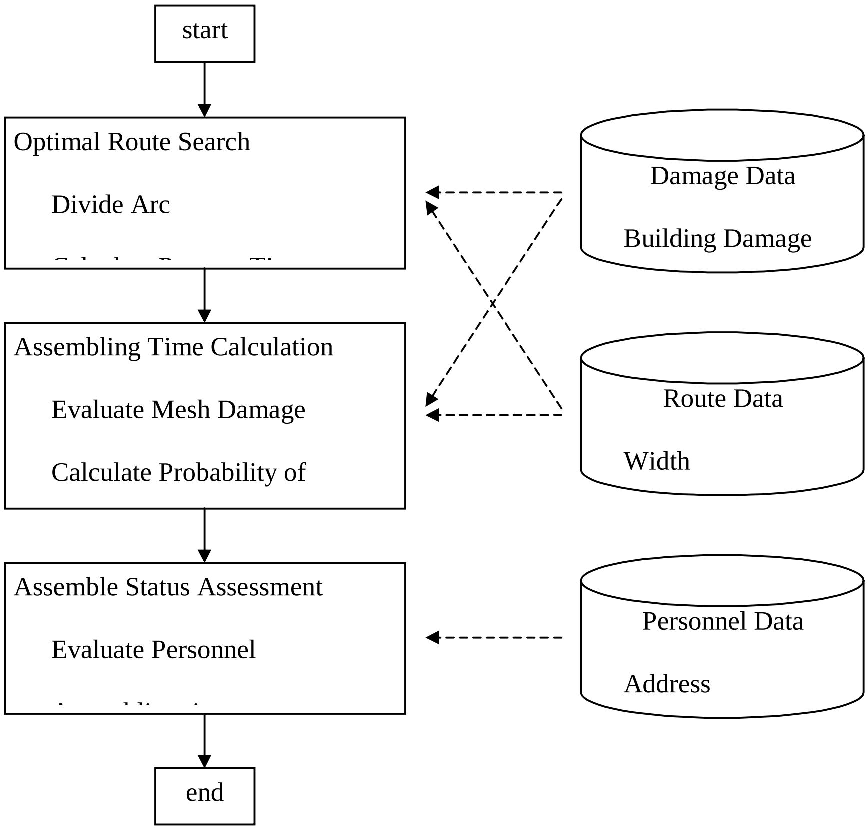


Figure 1 Framework of the System

METHOD

Passage Time of Arc

Figure 2 illustrates the concept of evaluation of the passage time. The passage time T of an arc is calculated by the following equation,

$$T = \sum_{i=1}^{n} \frac{L_i}{v / C_i} + T_{\sup} \ , \tag{1}$$

where L_i is a length of segment i, C_i is a delay factor of segment i and v is a velocity. $T_{\sup}$ is a supplement time corresponding to the individual factor, such as bridge collapse. n is the number of segments in the arc.

The delay factor newly introduced in this system corresponds to the fact that the velocity of the personnel cahnges segment by segment. This factor will be determined by the engineering judgement, considering the structural damage along the arc, the fire expansion, and the width of road. It can be noted that the fire expansion is also the function of the damage of wooden structure.

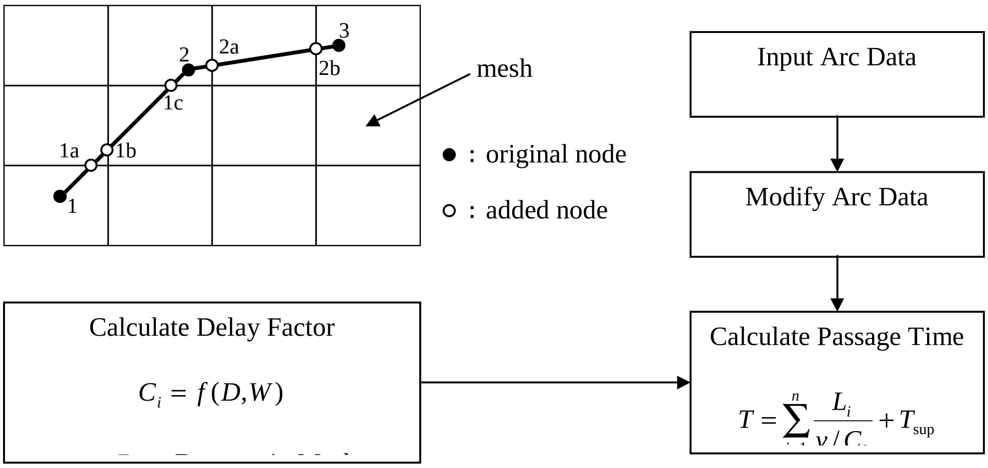


Figure 2 Evaluation of Passage Time of Arc

The delay factor C is evaluated by the following equations,

$$C = C_1 \cdot (1 - R_f) + C_2 \cdot R_f \ , \qquad (2.1)$$

$$R_f = \frac{n_f}{N} \ , \qquad (2.2)$$

where C_1 is the delay factor in the case that no fire expansion exists and C_2 is the delay factor in the case that fire expansion exists, respectively. n_f is the number of wooden buildings on fire and N is the number of buildings in the mesh considered. Both C_1 and C_2 are assumed to be given by the following equations,

$$C = a \cdot D^b + c \ , \qquad (3.1)$$

$$a = C_{100} \ , \qquad (3.2)$$

$$b = \frac{\ln(C_{50} - C_0) - \ln(C_{100} - C_0)}{\ln(50) - \ln(100)} \ , \qquad (3.3)$$

$$c = C_0 \ , \qquad (3.3)$$

where C_0, C_{50} and C_{100} are coefficients corresponding to the damage rate of 0%, 50% and 100%, respectively. D is the damage rate, which is calculated by the following equation,

$$D = D_w \cdot R_w + D_{nw} \cdot (1 - R_w)/2 \ , \qquad (4.1)$$

$$R_w = \frac{n_w}{N} \ , \qquad (4.2)$$

where D_w is a damage rate of wooden building and D_{nw} is that of non-wooden building. n_w is the number of wooden buildings and N is the number of buildings in the mesh considered.

Coefficients C_0, C_{50} and C_{100}, which are given as inputs in the analysis, control the relationship between the damage rate and the delay factor as shown in Fig. 3. Also indicated in Table 1 are the values employed in this system, which are obtained based on the expert's opinion. It may be noted that these coefficients must be assigned for the combination of the status of fire expansion and width of arc.

Table 1 Example of Delay Factors (in the case of walk)

Width of Arc	Fire Expansion	Delay Factor		
		***C*$_0$**	***C*$_{50}$**	***C*$_{100}$**
13 -	no	*1.0*	*1.0*	*1.2*
	yes	*1.2*	*1.2*	*1.2*
5.5 - 13	no	*1.0*	*1.1*	*1.4*
	yes	*1.4*	*1.4*	*1.4*
3 - 5.5	no	*1.0*	*2.0*	*5.0*
	yes	*5.0*	*5.0*	*5.0*
0 - 3	no	*1.0*	*3.0*	*9.0*
	yes	*9.0*	*9.0*	*9.0*

Optimal Route

The optimal route is searched by the Dijkstra's method, which is frequently used in the similar problems. This method gives the optimal routes for every nodes simultaneously with the information about the time required to the destination. This time is abbreviated as T_{m-i} for node *i*.

In the case when there may exist plural destination, this system can propose the nearest one by comparing the result for each destination. Namely, each personnel can know where to go for each scenario earthquake as the prior information.

For the convenience, the procedure of Dijkstra's method is illustrated. Figure 4 shows the example with the destination node [8]. Figure 5 shows the process of determining the optimal route by searching the shortest node step by step. In Fig. 5, black nodes are determined node, which have information regarding to the node to go and the time required. White nodes are free nodes connected to the determined node. Solid lines are the route identified by this procedure.

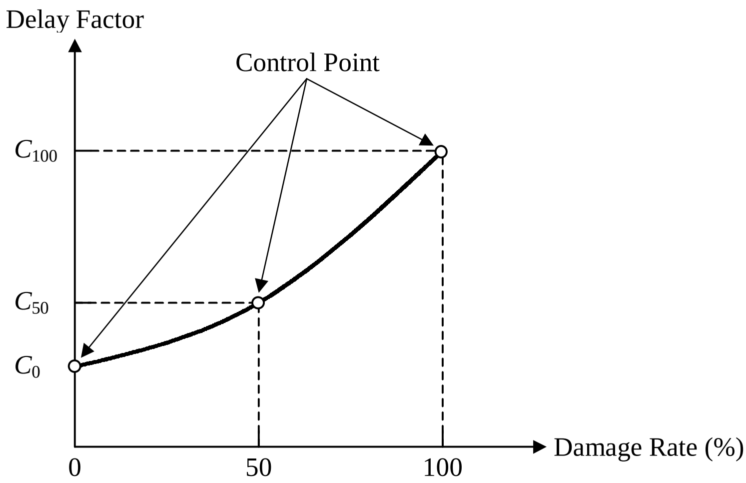


Figure 3 Relationship between Damage Rate and Delay Factor

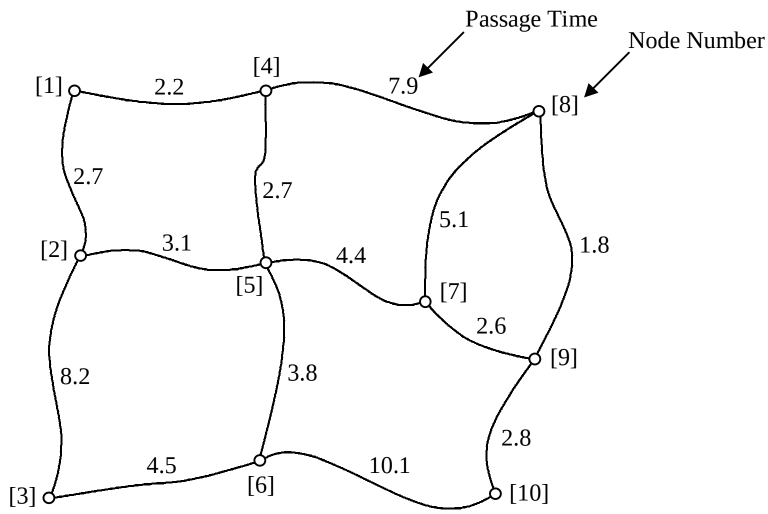


Figure 4 Example Route for Illustration

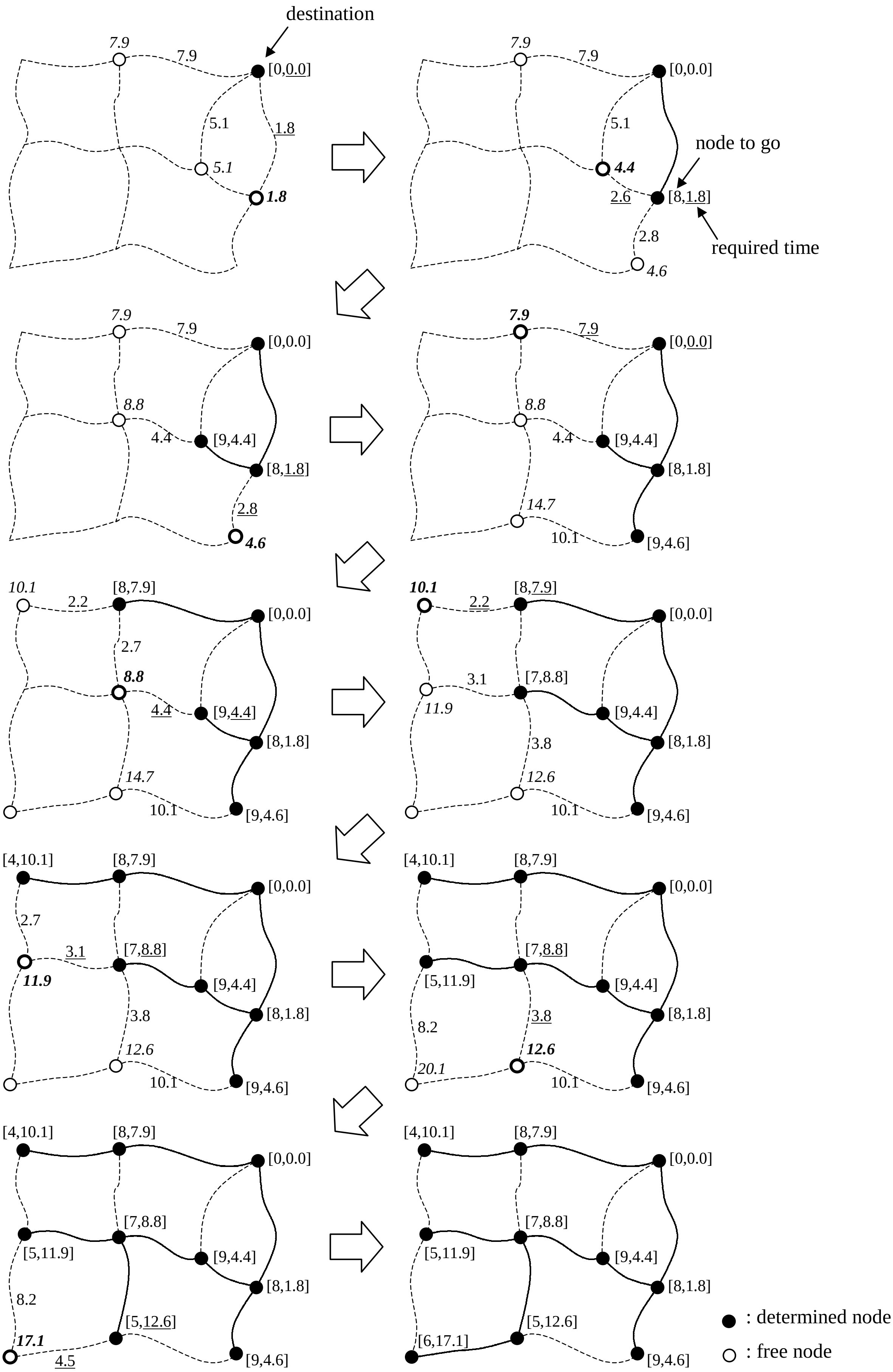


Figure 5 Process for searching the optimal Route

Damage in Mesh

Using damage rate in mesh, following items are estimated in this system; a damage rate of personnel, an assembling probability and a time for commencement of move.

A damage rate of personnel D_p is calculated using the following equation,

$$D_p = D_w \cdot R_w + D_{nw} \cdot (1 - R_w) \ , \tag{5.1}$$

$$R_w = \frac{n_w}{N} \ , \tag{5.2}$$

where D_w is a damage rate of wooden building and D_{nw} is that of non-wooden building. n_w is the number of wooden buildings and N is the number of buildings in the mesh considered. It must be noted that the individual data regarding to the personnel's are not considered in the calculation, since they are not available generally. Therefore, if the data were available, more accurate estimation could be done.

The assembling probability P_a is calculated using D_p in the equation (5.1) as follows,

$$P_a = 1 - D_p / 2 \ . \tag{6}$$

The above simple relationship is derived the existing study by authors. In reality, the assembling time differs due to the individual situation, such as the time when an earthquake occurs, damages of personnel himself and/or his family, and so on. It is unfortunately the fact that enough data to reinforce the above assumption have not been obtained yet.

The time for commencement to move means the necessary time to secure the safety of relatives, to give first aid treatment to the injured, and so on. As stated in P_a, there are few date concerning the time. Therefore, the following equation based on the other study is employed in this system to obtain the time for commencement T_c,

$$T_c = 5 \cdot \sqrt{D_p - 0.1} \qquad \text{if } D_p > 0.1 \ , \tag{7.1}$$

$$T_c = 0.0 \qquad \text{if } D_p \leq 0.1 \ . \tag{7.2}$$

Time Estimation

The total time from the occurrence of an earthquake to the arrival can calculated by the following equation,

$$T_k = T_{c-k} + T_{m-i} + T_{n-ik} \ , \tag{8}$$

where T_k is the total time of mesh k. T_{c-k} is the commencement time of mesh k given by the equation (7.1) or (7.2). T_{m-i} is the required time of node i, which is estimated with the optimal route by the Dijkstra's method. T_{n-ik} is the time required from the centre of mesh k to the nearest node i.

The search of the nearest node is simply done by calculating the distance between the centre of mesh and the node. The estimation of T_{n-ik} is carried out using the same way for the calculation of passage time of arc.

IMAGE OF OUTPUT

Figure 6 illustrates the locations of personnel with cross showing the damage of arc. Figure 7 shows the optimal route. Figure 8 shows the damage rate of personnel. Damage rates are given for mesh in the identified area. Figure 9 illustrates the relationship between the elapsed time and the number of personnel arrived. It must be noted that the number indicated the expected valued, namely, the number of personnel times the assembling probability.

CONCLUSIONS

This paper describes the development of the assembling time map, which will be helpful for the realistic action for seismic countermeasure. This system still has a lot of assumption due to the fact that the available data are not in hand. However, authors think that the first priority is to build up the framework and the second priority is to brash up the system by modifying the methodology and by collecting data.

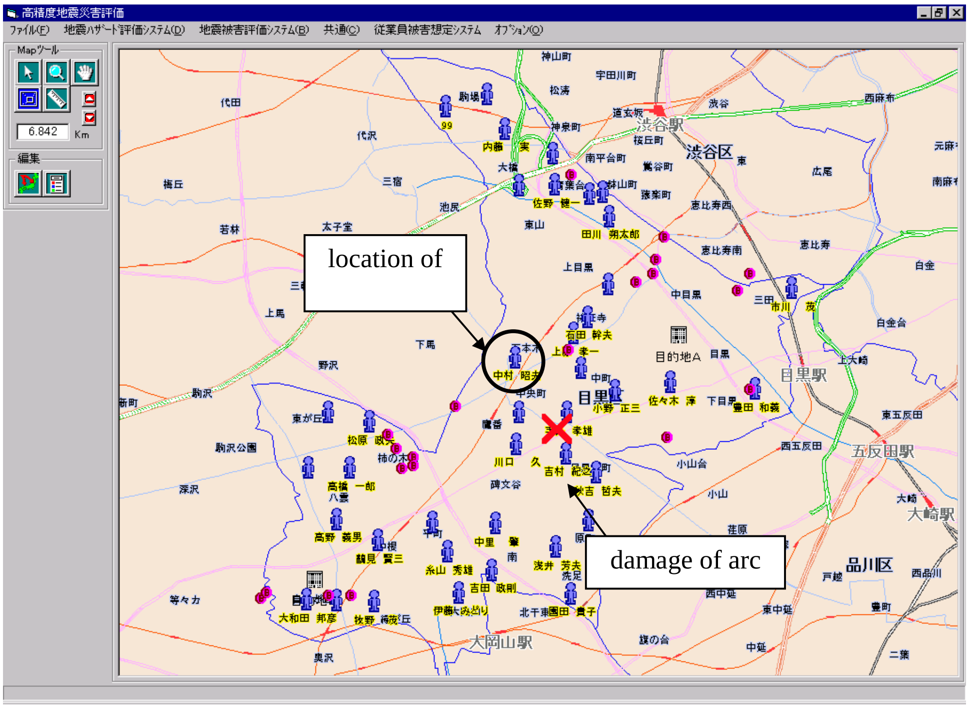


Figure 6 Location of Personnel

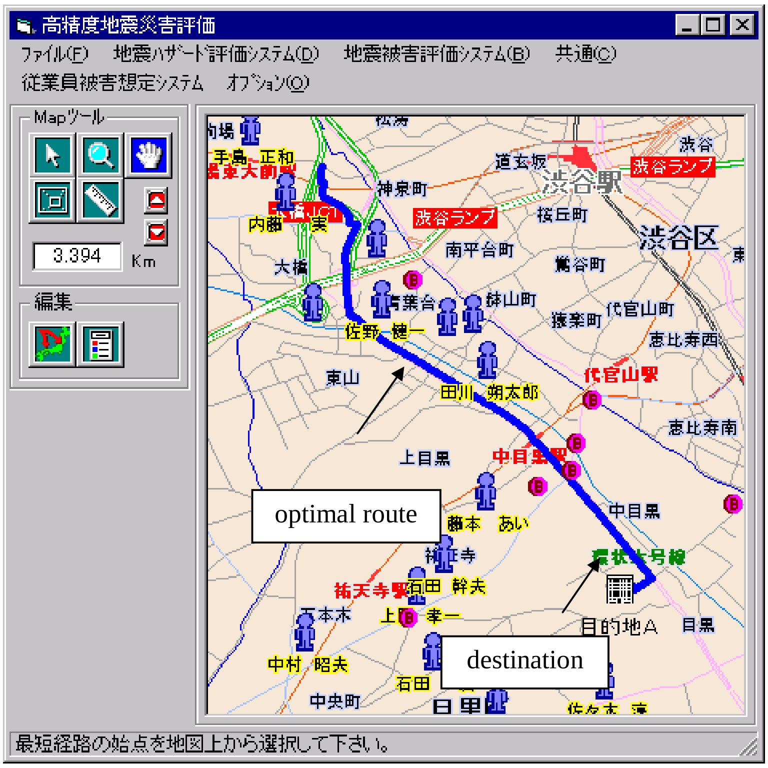


Figure 7 Indication of the Optimal Route

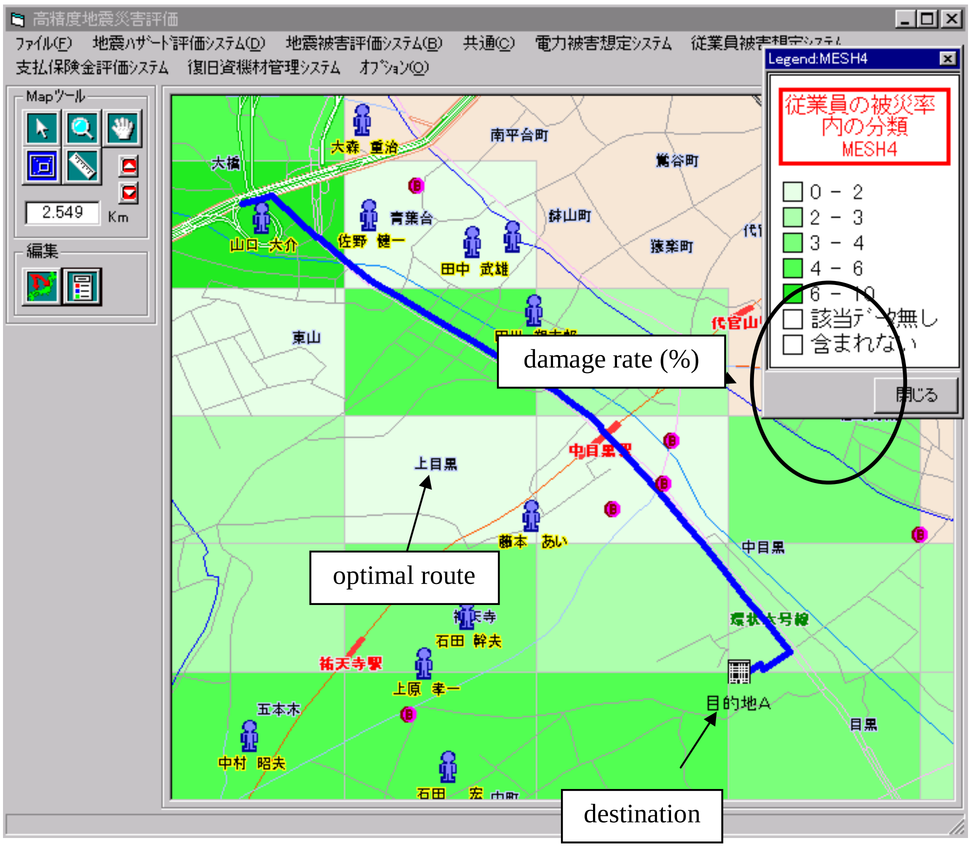
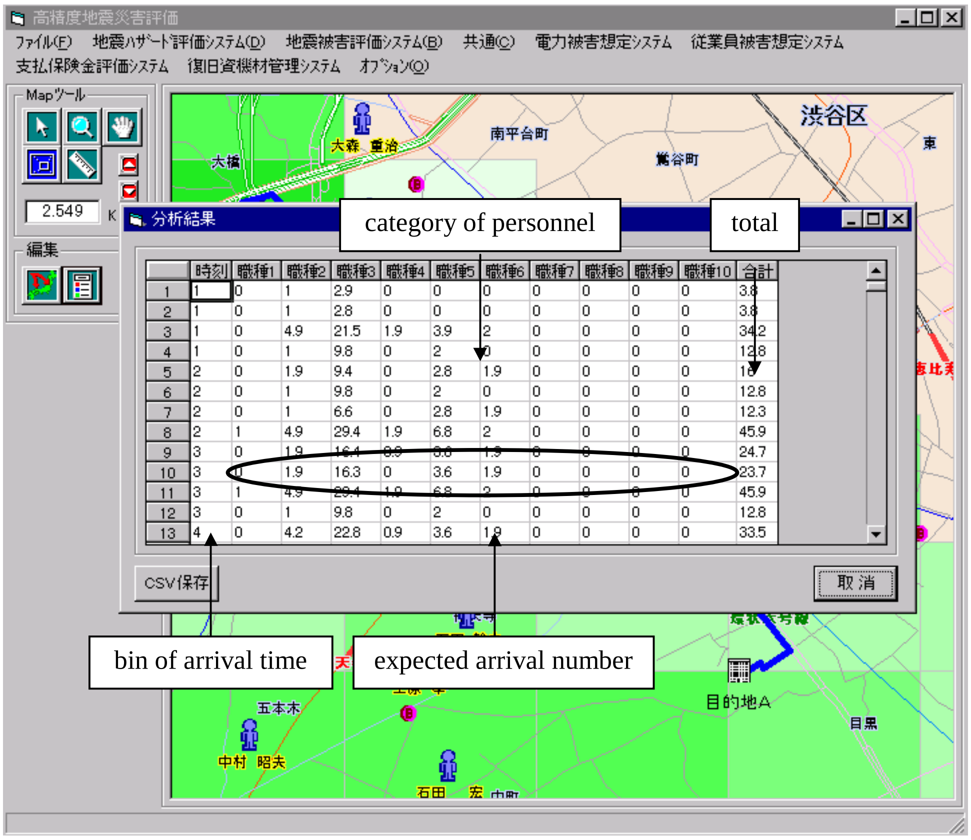


Figure 8 Damage Rate of Personnel



	時刻	職種1	職種2	職種3	職種4	職種5	職種6	職種7	職種8	職種9	職種10	合計
1	1	0	1	2.9	0	0	0	0	0	0	0	3.8
2	1	0	1	2.8	0	0	0	0	0	0	0	3.8
3	1	0	4.9	21.5	1.9	3.9	2	0	0	0	0	34.2
4	1	0	1	9.8	0	2	0	0	0	0	0	12.8
5	2	0	1.9	9.4	0	2.8	1.9	0	0	0	0	16
6	2	0	1	9.8	0	2	0	0	0	0	0	12.8
7	2	0	1	6.6	0	2.8	1.9	0	0	0	0	12.3
8	2	1	4.9	29.4	1.9	6.8	2	0	0	0	0	45.9
9	3	0	1.9	16.4	0.9	3.6	1.9	0	0	0	0	24.7
10	3	0	1.9	16.3	0	3.6	1.9	0	0	0	0	23.7
11	3	1	4.9	29.4	1.9	6.8	2	0	0	0	0	45.9
12	3	0	1	9.8	0	2	0	0	0	0	0	12.8
13	4	0	4.2	22.8	0.9	3.6	1.9	0	0	0	0	33.5

Figure 9 Relationship between Elapsed time and Arrival Number